Using Simulation to Evaluate Funding Models for SDI Implementation

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Key words: SDI funding models, simulation, system dynamic simulation modelling

SUMMARY

As Spatial Data Infrastructures (SDIs) evolve and the nature of government spending policies changes, it is evident that current funding arrangements for SDI implementation and maintenance will no longer be adequate. Funding from the budgets of national mapping agencies and 'one-off grants' will no longer be capable of funding the efficient implementation and maintenance of the next generations of SDIs. Efficient implementation and maintenance of future SDIs will require structured long-term funding models.

Authors (e.g. (Rhind, 2000); (Urban Logic, 2000); and (Giff and Coleman, 2003)) have proposed different sets of funding models for the financing of future generations of SDIs as a solution to this problem. One of the drawbacks of these models is that they are generally conceptual in nature. That is, they were designed for a generalized implementation environment and, therefore, may not be specific enough for an individual environment. The problem facing program coordinators is the selection of models that are most suitable to their implementation environment. A possible solution to this problem is the design and or selection of methodologies to evaluate the application of the models in specific implementation environments.

The authors propose the usage of *System Dynamic Simulation Modelling* (SDSM) as a possible technique for the evaluation of SDI funding models applied to a specific implementation environment. SDSM will enable program coordinators to track the application of the models in a particular implementation environment over time and also, observe their reaction to changes in key variables operating within the implementation environment. This technique (SDSM) allows program coordinators to replicate their implementation environment and manipulate variables they deemed to have the most effect on the funding of an SDI. The aim of this paper is to discuss the concept of the application of SDSM to the evaluation of funding models.

This paper will briefly review the proposed conceptual funding models and categorize them based on the type of SDI they are most suited to fund. The second section of the paper will then discuss the concept of SDSM and its application to the evaluation of the funding models. This is followed by examples of system dynamic simulation models for different SDI implementation environments.

This paper is geared mainly towards program coordinators and members of the SDI community interested in the economic issues associated with an SDI. The information presented in this article will greatly assist these managers in selecting, customizing, designing, and evaluating specific funding models for SDI implementation in their environment.

Using Simulation to Evaluate Funding Models for SDI Implementation

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1. INTRODUCTION

The increase usage of spatial information (SI) by a wide sector of today's society has fuelled the demand for accurate and reliable spatial information in the different format required by the market (Onsrud et al., 2004). To facilitate better access to SI, at least 50 countries have implemented different qualities of *Spatial Data Infrastructure* (SDI). (See (Onsrud, 1999) for a list of the different SDI initiatives across the world.) In the developed world, these first-generation SDIs are at the end of their current funding arrangements. Therefore, new funding arrangements will be required for the next generation of SDIs. Also, SDI initiatives now underway in emerging nations are in need of structured funding arrangements for their efficient implementation.

To address this problem, authors (e.g. (Rhind, 2000); (Urban Logic, 2000); and (Giff and Coleman, 2003)) have proposed different sets of funding models for the financing of future generations of SDIs. One of the drawbacks of these models is that they are generally conceptual in nature. They were designed for a generalized implementation environment and therefore, may not be specific enough for an individual environment. The problem facing program coordinators is the selection of models that are most suitable to their implementation environment. A possible solution to this problem is the design and or selection of methodologies to evaluate the application of the models in specific implementation environments.

The authors—based on research carried out at the University of New Brunswick— propose the usage of *System Dynamic Simulation Modelling* (SDSM) technique as a possible method for the evaluation of SDI funding models applied to a specific implementation environment. SDSM will enable program coordinators to track the application of the models in a particular implementation environment over time and also, observe their reaction to changes in key variables operating within the implementation environment. This technique (SDSM) allows program coordinators to replicate their implementation environment and manipulate variables they deemed to have the most effect on the funding of an SDI. The aim of this paper is to discuss the concept of the application of SDSM to the evaluation of funding models.

2. FUNDING MODELS

To address the need for structured, long term funding models for the implementation and maintenance of the next generations of SDI initiatives, the authors designed and or adopted twenty different taxa of funding models. The models were designed to fund different categories of SDI based on their classification and their implementation environment. (See (Giff and Coleman, 2003 and 2003b) and (Giff, 2005).) To facilitate the design of the funding models, SDIs were classified according to the product they facilitate (i.e. spatial information as public goods or a quasi-public goods), the levels of SDI (i.e. national, regional or local), the government structure influencing their implementation and the implementation environment.

Table 1 lists selected taxa of funding models the authors consider to be more applicable to the implementation of the different categories of SDIs and their implementation in a variety of environments. (See (Giff, 2005) for a complete list and description of the funding models.) The selection of these taxa was based on a qualitative analysis of the funding models designed by the authors (see (Giff, 2005)), and an evaluation of the funding approaches employed by different mapping and SDI initiatives around the world. (See (Giff and Coleman, 2003a).)

Table 1: Taxonomy of Selected Funding Models For SDI implementation and maintenance

Taxon	Description
Government Funding	This term is used to refer to the funding of an SDI from the budgets of the different levels of governments and also, from the different government ministries within each level of government. These funds are derived from general taxation.
Public Sector Funding	This represents funding from quasi-government organisations (i.e. Crown Corporations or Statutory Bodies). Although these organisations answer to government they are self-sufficient and do not rely on taxes to balance their budgets.
Special Taxation	This represents a positive or negative imposition of taxes on the general public or on selected groups for the sole purpose of funding SDI implementation. In this model positive taxation can be used as incentives to encourage investment in an SDI while negative taxation can be used to raise revenue for investment.
Partnerships	The taxon partnership covers the collaboration amongst the different sectors of the society aimed at implementing an SDI. The collaboration usually involves the pooling of resources (financial and non- financial) to efficiently implement an SDI. Under the umbrella of partnership, several sub-taxa exist each with its own unique characteristic.
Government Partnerships	The idiom here is used to define the arrangement amongst the different levels of government in pooling resources for the efficient implementation of an SDI.
Public Sector Partnerships	This sub-taxon of Partnership is used to describe the collaboration amongst different public sector bodies in implementing an SDI. Again the collaboration can be financial, non-financial or a combination of both.
Government-Private Sector Partnerships	The term is used to represent the collaboration amongst the different levels of governments, quasi-government (public sector) organisation and the private sector in implementing an SDI.
Matching Ratios	This model is included under this taxon because it involves two or more parties working together to fund SDI implementation. In this model one partner (e.g. federal, province, local government, NGOs, private sector, or community groups) would match (according to the specified ratio) the amount of

Taxon	Description
	funds invested into the SDI by the other partner(s).
Financial Instruments	This is the umbrella for all the funding models that are available in the capital market. These financial instruments are customized for their application in SDI implementation. Examples of the alternative funding models falling in this category are described as sub-taxa below.
User Fees	This term is used to represent the different types of fees charged to the user for accessing spatial information facilitated by the SDI.
Private Sector Funding	This taxon includes all the models that are built solely on direct private sector investments into the development of an SDI.
Limited-Recourse Structures	This includes all the models that promote the different types of build, own, operate or transfer systems. In this category the private sector—depending on the specific model—will undertake the construction, financing, operating and maintenance of the infrastructure for a limited concession period (Buljevich and Park, 1999).

3. MODEL EVALUATION TECHNIQUES

The funding models were designed for the implementation and maintenance of different categories of SDIs and therefore, some models are more applicable to a particular type of SDI than others. This presents a problem to program coordinators in selecting the most appropriate funding model(s) for their SDI. They must determine which models accurately and realistically captured the key components of their system and thus are capable of funding their SDI.

To accomplish this, the authors recommend that program coordinators perform a quantitative analysis on the funding models. Expected from this analysis is the identification of the relationship amongst the different models, their reaction to changes, and their performance when applied to funding an SDI under specific conditions over time. For an analysis of this nature, the authors identified three techniques (McKibbin and Wilcoxen, 2004); (Grcic and Munitic, 1996 and 1997); and (Forrester, 1991):

- *The actual testing of the models in a real life situation* —Probably the most ideal method of evaluating a model, it involves implementing the model in a real world environment. A case study is performed on the implementation and the results are analysed to determine whether or not the model is performing as expected. The drawback of this technique is that it can be time consuming and expensive.
- *The" business as usual" versus target approach* — In this method an extensive analysis of current practice is carried out to determine the ability of the current practice to achieve the goal. A model of the improved system is then created and compared with the old system to illustrate which of the two achieves the goal, in the most efficient manner
- *Computer Simulation Modelling* — In this technique computer models are used to imitate (simulate) the relevant real world operation(s) of a system. These models are so designed to mimic the behaviour of the system (real world) to events that may take place

over a given period of time within the system's environment (Law and Kelton, 1991); and (Shannon, 1998). Input variables are varied to determine their effects on the performance of model and the output of the model. The results of the simulation are then analysed to evaluate the effectiveness of the model.

4. SYSTEM DYNAMICS SIMULATION MODELLING

The simulation technique—specifically *System Dynamics Simulation Modelling* (SDSM)—was investigated as a tool to analyse the performance of the funding models under specific implementation conditions. Jay W. Forrester made this technique popular through his early publications *Industrial Dynamics: A Major Breakthrough for Decision Makers* (Forrester, 1958); *Industrial Dynamics* (Forrester, 1961); and *Urban Dynamics* (Forrester, 1969). System dynamics modelling—an approach used to model complex, non-linear systems—involves the usage of feedback-loops, flows/rates, levels/stocks, and time-delays to facilitate the integration of the qualitative and quantitative variables operating within the boundary of the system (Forrester 1980); (Forrester 1991); and (Dudley and Soderquist, 1999). Forrester (1969) defined the building blocks of system dynamics modelling (SDM) (illustrated in Figure 1) as follows:

- *Feedback Loop*— The fundamental building blocks of the SDM technique. It is a structure within which a decision variable (flow) controls an action that is integrated into the system to generate a system level. Information pertaining to the level is then fed back to the decision variable, which is in turn used to control the flows (Figure 1).
- *Level*— An accumulation or integration of flows (inflows or outflows) over a period of time. The value of a level can only be changed by a flow. An example of a level in the context of this paper would be a pool of funds for SDI implementation.
- *Flow*—A variable that changes a level over a period of time. Flows are of two types: an inflow that increases a level, and an outflow that depletes a level. In summary, flows are statements of system policies that determine how information about the system is translated into an action(s). In the concept of an SDI a funding model or a category of funding models would be classified as a flow.

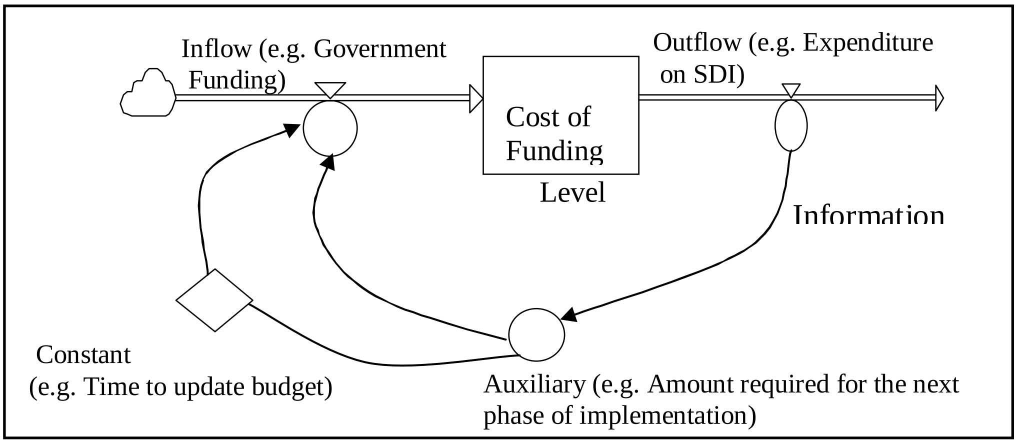

Figure 1: An illustration of the Symbol Used in a Feedback Loop

Although the above components are the main building blocks of SDSM, the authors also used the following components in the creation of the system dynamic simulation (SDS) models of the SDI funding environment:

- *Auxiliary*—Used to make the relationship amongst variables more explicit. This is often achieved through the calculation of intermediary values that are used to update flows. Variables affecting the funding models (e.g. government policies) are examples of auxiliary.
- *Constant*—Used to represent variables whose values do not change with time. A constant can be used as an input to a flow or an auxiliary.

To summarize, system dynamics technique represents—in the form of models—the real world environment in terms of closed, feedback-dominated loops, non-linear, and time-delayed systems (Meadows and Robinson, 1985).

The authors investigated the potential of system dynamics simulation modelling (SDSM) technique to analyse the funding models because of the properties of this modelling technique that are very applicable to the SDI implementation environment. These properties include:

- The ability of the technique to include in the model qualitative components of the environment, especially those involving human behaviour and other soft variables (Dudley and Soderquist, 1999);
- SDSM through numerical integration allows the modeller to evaluate complex systems that do not have explicit mathematical solution (e.g. an SDI environment);
- SDSM supports the translation of the model into a computer-based environment through the usage of software packages. This is a key feature since it allows the modeller to focus more on the modelling rather than programming languages; and
- Finally the models produced from the SDSM technique can be modified to evaluate both changes in the variables as well as changes to the overall structure of the model. This allows for more comprehensive and faster evaluation of the model environment.

For more details on the properties of SDSM, see (Barlas, 1989); (Forrester, 1991); (DeTombe and Hart, 1996); (Grcic and Munitic, 1996); (Dudley and Soderquist, 1999); and (Love et, al., 2002).

5. BUILDING THE SIMULATION MODELS

The SDS models for SDI funding—using the models proposed by the authors—were created using Powersim® software. Powersim® was chosen over the other simulation software because of its analytical capability, the wide variety of graphical methods it offered for the presentation of the simulation results, its ability to graphically display the model and, finally, the easy availability of a trial version.

Twelve simulation models were created to evaluate the performance of SDSM to SDI funding. (See Giff, 2005.) However, for the purpose of conciseness, two SDS models of different implementation environments will be presented along with the results of the simulation runs. These simulation models will demonstrate the ratios of funding amongst the different funding models at the start of a period and track them over time. Over this time frame, the implementation environment will also be altered to detect the effects of changes in different variables on the funding models. The results obtained from the simulation runs will be used to analyse the funding models in terms of: (1) their ability to provide long-term funding for the implementation and maintenance of an SDI; (2) their ability to be integrated into a funding pool to provide long-term resources for SDI implementation; (3) their sensitivity to changes within the environment; and (4) the classification and level of an SDI they are best suited to fund.

Although all the simulation models were designed using the basic rules of SDSM, individual models were designed using knowledge of the specific implementation environment. For a particular environment, the specific factors affecting the performance of the funding models within that environment were incorporated into the simulation model. For example, key factors incorporated into the funding environment of an SDI categorized as a classic infrastructure would be: government policies, pricing policies, and the mandate of SI related organisations to name a few. On the other hand, the simulation models for the funding environment of a sustainable SDI would require the incorporation of the following key factors in their design: private sector activities, capital market activities, interest rates, the demand for SI and government policies (Table 2). In Table 2, key factors affecting the funding models are categorized by the type of SDI they affect the most. This categorization is used to illustrate the factors that are incorporated into the different simulation models. For example, it can be seen from Table 2 that the key factors to be included in the different simulation models for a national SDI (NSDI) would be government structure and policies, legislation, supporting infrastructure, existence of data, and the strength of the SDI community.

Table 2: An Illustration of the Factors Affecting the Funding of an SDI and the Type of SDIs they affect the most

Categories and Levels of an SDI	Factors Affecting The Funding Models and The Funding Environment										
	Government Structure	Government Policies	Market Activities	Interest Rates	Private Sector Activities	Legislation	Culture	Demand for SI & Value added products	Supporting Infrastructures	Existence of Data	Strength of the SDI Community
Classic Infrastructure	X	X				X	X		X	X	X
Sustainable Infrastructure	X	X	X	X	X	X	X	X	X	X	
Network Infrastructure		X	X	X	X	X	X	X	X	X	
National SDI	X	X				X			X	X	X
Provincial SDI	X	X	X	X	X	X		X	X	X	X
Local SDI	X	X	X	X	X	X	X	X	X	X	X

In summary, the factors included in a simulation model will depend on the environment to be modelled, the type of SDI to be implemented, and the combination of funding models to be used in the implementation and maintenance of the SDI.
The factors affecting the design of the funding models are important components of the simulation models. The importance of these factors will differ from simulation model to simulation model. Their importance to a funding environment can be emphasized through the use of sub-models in a simulation model. These sub-models are used to model the integration of different components a factor may contain and their effects on the funding of an SDI.
The relationships amongst the components of the simulation models (e.g. the funding models, factors affecting them, and the cost of implementation) are incorporated into the models through the use of codes. That is, the relationships are interpreted mathematically (as best as possible) and represented in the simulation models as a series of equations. These equations include not only mathematical functions but also statements about the relationships. Simulation programming languages facilitate the integration of both mathematic equations and logic statements.

The results of the simulation runs (i.e. the output of the models) are usually presented as graphs mapping the relationships of the components over time. However, the results of individual components can also be presented graphically or numerically within the simulation model. These values can be represented as a fixed display in the model or achieved on demand by moving the cursor over the component in question.

6. INTRODUCTION TO THE EXAMPLES

The simulation models explored by the authors to illustrate the performance of the funding models ranged from simple scenarios to very complex scenarios. The complexity of the scenarios varied with the number and type of variables operating within the implementation milieu that are included in the simulation. The different taxa of funding models used to finance the implementation of the SDI will also contribute to the complexity of the simulation. That is, a simulation model may contain one or more of the taxa of models introduced in Table 1 with the possibility of each taxa having one or more sub-taxon. For example, if the partnership category is used in a simulation then this may involve the application of government partnerships, public sector partnerships, and government-private sector partnerships to name a few.

Before examining some of the more complex simulation models created by the senior author, this section will present simplified versions of a simulation model in an attempt to familiarize the readers with the concept of SDSM. Figure 2 represents a simplified version of a simulation model of the funding of an SDI at the local level. In this model, the SDI is funded using the following funding models: local government partnerships, local government-private sector partnerships and provincial government funding. In this simulation model the cost of SDI implementation is an assumed value and the simulation is run over a fifteen-year period (i.e. 3 government budgetary periods). The simulation model assumes that the implementation environment remains fairly constant for the duration of the run with an increase of ten percent in the cost of implementation per budget term. Other key assumptions made in the simulation are as follows: local government partnerships will fund sixty percent of the cost of implementation, local government-private sector partnerships will fund thirty percent, and provincial government funding will fund the remaining ten percent.

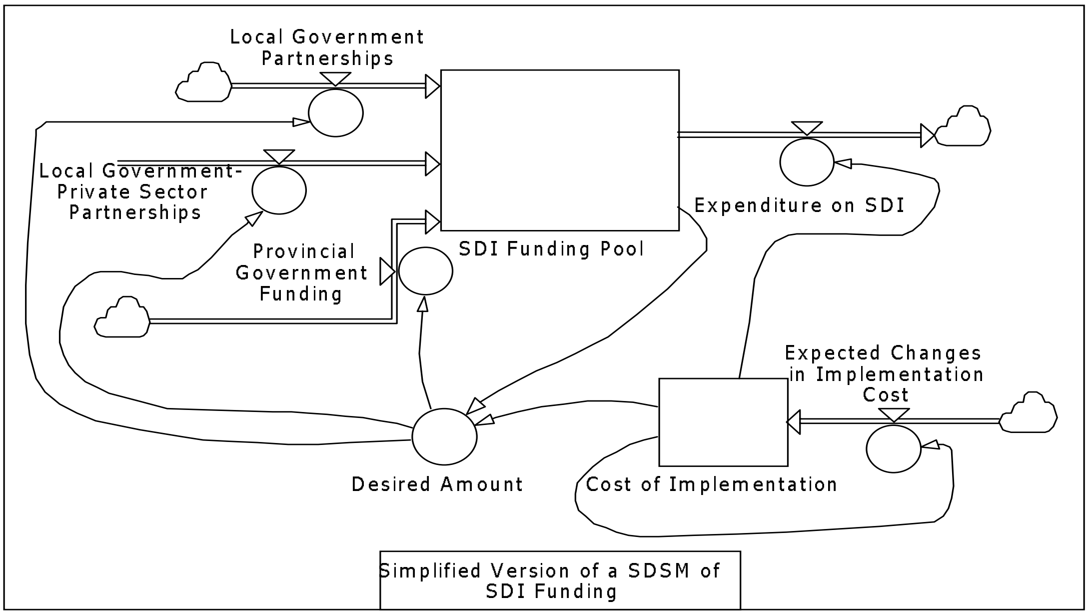

Figure 2: An Example of The Application of SDSM to SDI Funding

The results of the simulation run can be presented in a graphical format (Figure 4) or in a numerical format within the model. The results of this simplified example illustrate the changes in the amount of funds contributed by each model over the length of the run and the relationship amongst the models (i.e. the ratio of the funding models over time).

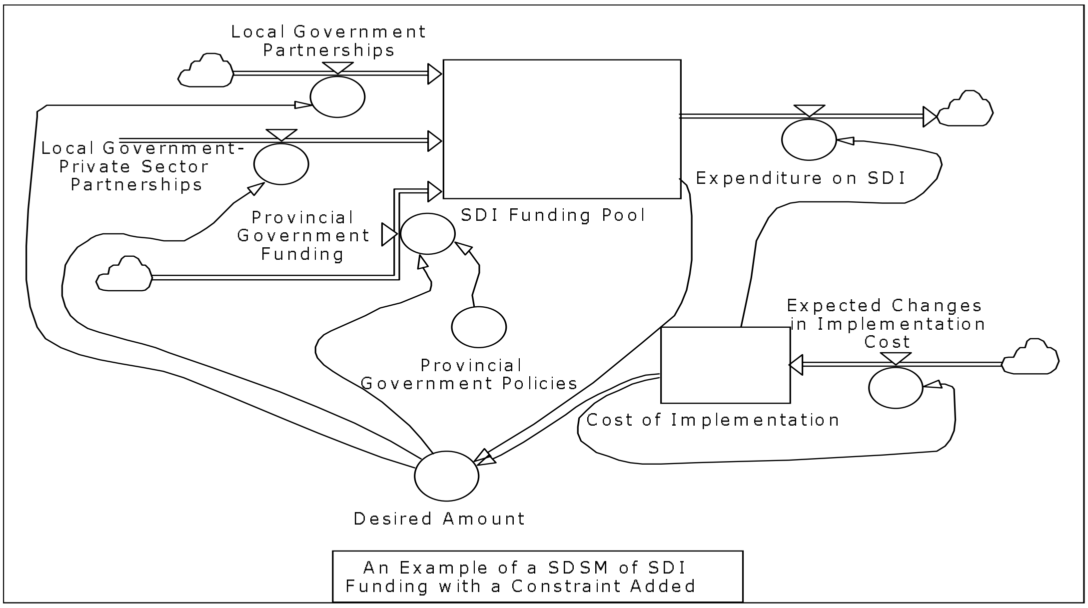

Figure 3: An Example of a SDSM of an SDI Funding Environment

To further demonstrate the capabilities of the SDSM to illustrate and compare the performance of the funding models it is necessary to adjust the simulation model to better reflect the application of the funding models to SDI implementation. Again, for the purpose of clarity only a single variable will be introduced into the simulation environment created previously and presented in Figure 2. The variable introduced to facilitate the demonstration is that of *provincial government policies* which will only affect provincial government funding in this simulation. In this simulation model (Figure 3) the assumptions made are similar to those of Figure 2 with the addition that provincial government funding will be cut in half after the first budget period. The simulation will attempt to illustrate the performance of the models in reaction to this change in the implementation environment. That is, the performance of the different funding models, and a comparison of their ratios over time under the specified conditions.

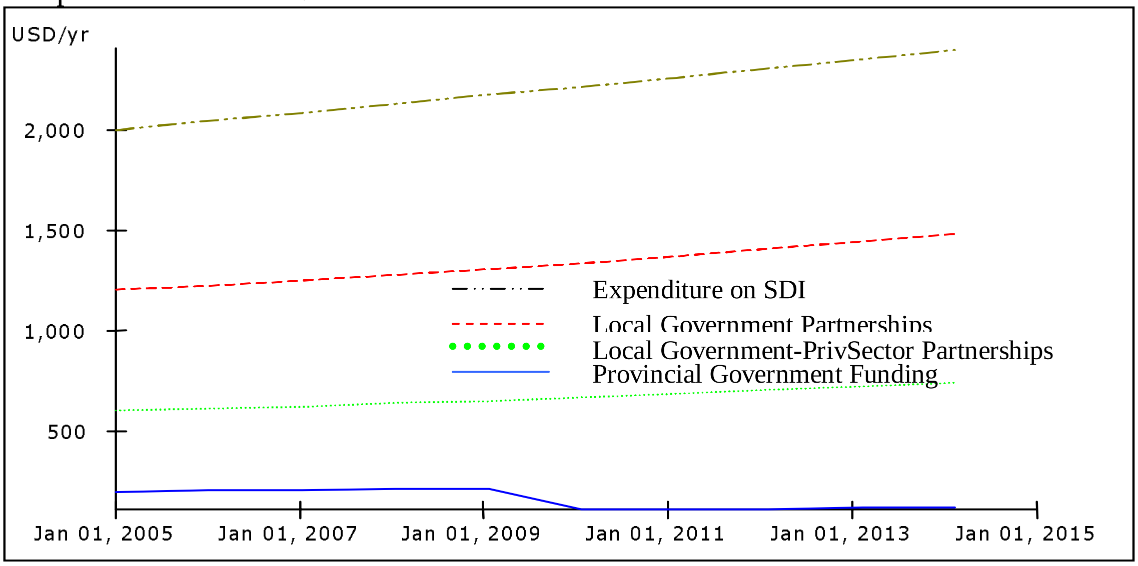

Figure 4: Results of a Simulated Environment With Changing Government Policies

Figure 4 illustrates the simulated performance of the funding models over a fifteen-year period. From the Figure it can be seen that local government partnerships and local government-private sector partnerships continue to fund the SDI at a constant rate. However, provincial government funding dipped at the end of the first budgetary term, as a result of the change in provincial government policies.

7. SYSTEM DYNAMIC SIMULATION MODELLING OF A SUSTAINABLE SDI

In this example the performance of selected funding models applied to the implementation of a sustainable SDI will be simulated. The funding models proposed for an SDI of this nature involved a mix of government and private sector funding, with the private sector playing a strong role (Figure 5). In Figure 5, the funding models (i.e. public-private sector partnership, public sector partnership, private sector funding, special loans, limited recourse funding, and government funding) are depicted as flows that are changing the value of the SDI funding pool (the level); while auxiliary variables are used to represent factors of the implementation environment that affects the funding models.

To illustrate the performance of the models when applied to an SDI of this nature, the simulation was run over a period of fifteen years (approximately three budgetary period). Over twenty simulation runs were performed with the values of different variables and combinations of variables being adjusted to reflect different scenarios of the implementation environment. However, in the example presented only the following variables were changed over time to identify the reaction of the funding models:

- *Changes in Interest Rate*—Interest rate was increased to determine the private sector reaction to funding an SDI in a high interest rate environment. Private sector reaction was important in this environment because the majority of the funding models here were private sector oriented. Also, investment in this type of SDI is expected to generate a surplus; and
- *Increase in the Cost of Implementation*—This aspect of the environment was simulated to measure the ability of the funding models to generate sufficient resources to fund an SDI whose cost of implementation exceeded the budgeted value.

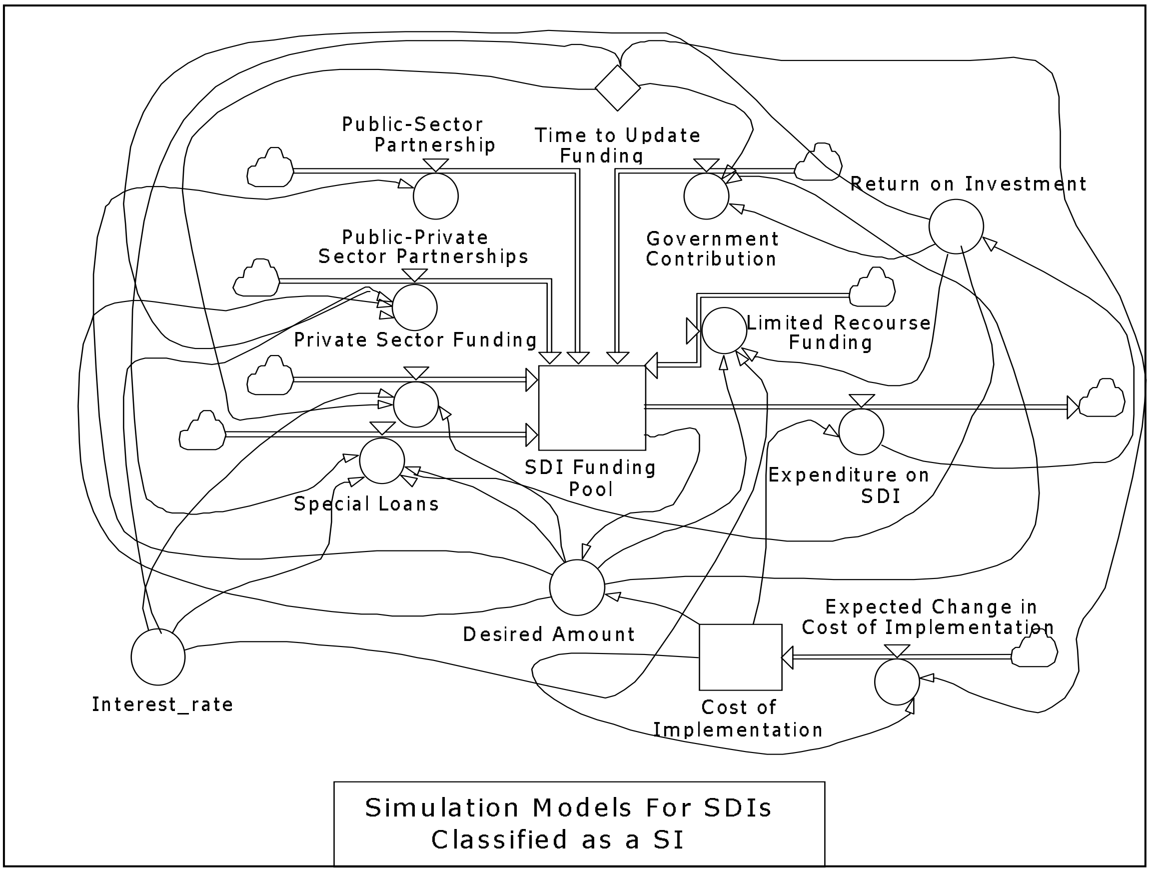

Figure 5: SDSM of Funding a Sustainable SDI

7.1 Results of the SDSM for a Sustainable SDI

Figure 6 illustrates the effect of an increase in interest rate on selected funding models for a sustainable SDI. In the graph investment from public-private sector partnership and private sector funding declined sharply as the private sector reduces their investment in an SDI for more favourable investments (e.g. Certificate of deposits, bonds and other high interest paying financial instruments). However, investment in the form of loans and public sector partnerships demonstrates an increase sufficient to cushion the effects of the shortfall. This infers that a combination of the funding models is capable of funding an SDI within an environment of changing interest rates.

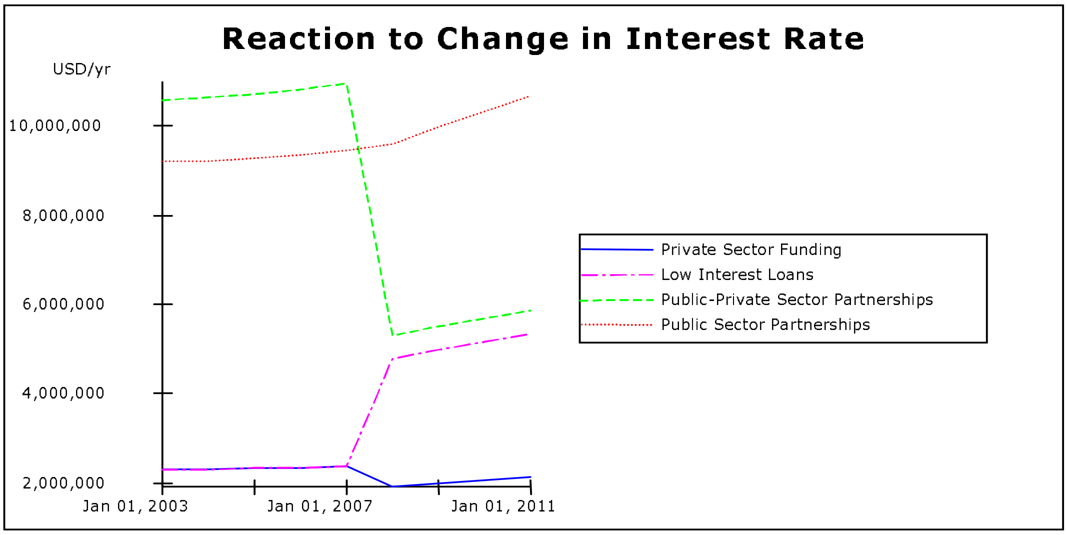

Figure 6: Reaction of The Funding Models to Changes in Interest Rates Over Time

The graph shown in Figure 7 is an illustration of the reaction of the funding models to multiple changes in the implementation environment. That is, their reaction to changes in interest rates and the cost of implementation. The graph shows that investment from public-private sector partnership increases steadily as the SDI matures and the demand for SI grows but as interest rates climb the investment falls. The shock reaction to an increase in interest rates is however, dampened somewhat by the increased demand for SI. Limited recourse funding also follows a similar pattern as public-private sector partnership. Loans, on the other hand, showed an overall increase driven by higher interest rates and increase usage of SI.

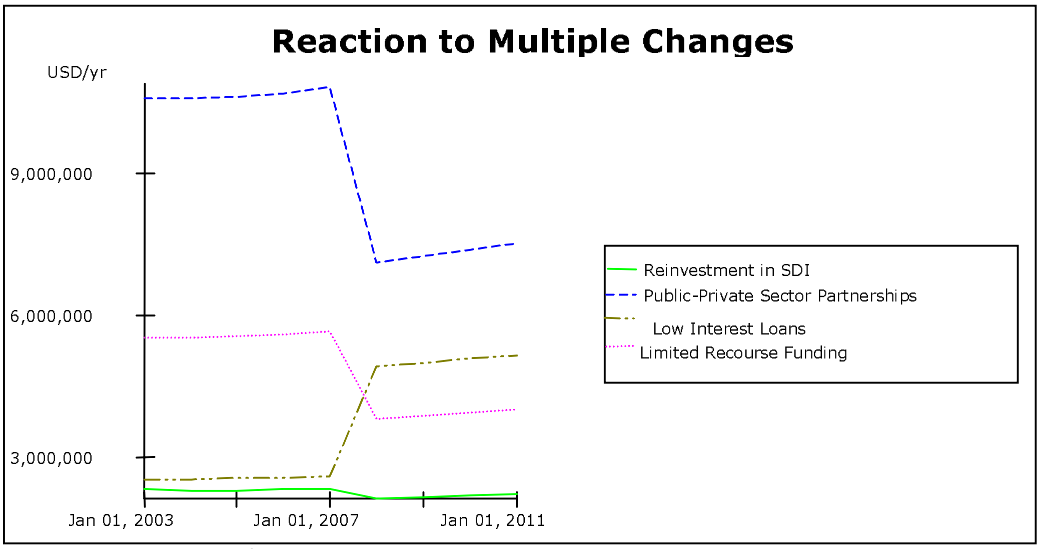

Figure 7: Reaction of Selected Funding Models to Multiple Changes

In addition to the simulation model presented in this paper the authors produced other simulation models for a variety of SDIs and different implementation environments. In these simulation models key variables were adjusted to reflect different implementation scenarios. Based on the results of these simulation runs and a qualitative analysis, the authors were able to qualify the application of the main taxa of funding models to the different categories of SDIs (Table 3). The models were ranked according to their application to three categories of SDIs:

- *Classic Infrastructure*—This category is used to represent SDIs deemed to be the facilitator of public goods. For SDIs within this category, the capacity or usage is of less importance than their ability to facilitate the provision of public goods to support the social, political, and economical well being of the society.
- *Network Infrastructure*—One of the key objectives of an SDI falling in this category is to generate a surplus. Therefore, the capacity of the network is very significant in this category. The components of the SDIs within this category are viewed as nodes of the network. Investments in the nodes or the SDI, in general, will depend on the capacity the nodes or the SDI is capable of handling over a fixed period of time. Therefore, in order to secure investment for this type of SDI, the SDI or nodes of the SDI must demonstrate that it has the capability to operate at a capacity that will generate satisfactory returns on investment.
- *Sustainable Infrastructure*—This category is used to represent SDIs facilitating the production and distribution of quasi-public goods. These SDIs fall between the two extreme categories of classic infrastructure and network infrastructure. SDIs in this category are not expected to generate optimal returns on investments but are expected to generate sufficient surplus to facilitate their maintenance.

Table 3: Most Suitable Application of the Funding Models

Funding Models	SDI Classification							
Taxon of Models	Classic Infrastructure			Sustainable Infrastructure		Network Infrastructure		
	Local	Regional	National	Local	Regional	Component	Niche	Local
Government	F	S	S	-	F	F	-	-
Department Operating Funds								
Quasi-government	S	S	F	F	F	F	-	F
Special taxation	-	F	S	-	-	-	-	-
Partnerships								
Government	S	S	S	S	S	-	-	-
Public Sector	S	S	F	S	F	F	-	-
Govt.-Private	S	S	F	S	S	F	-	F
Matching ratios	F	S	S	-	F	F	-	F
Financial Instruments								
Bonds	-	F	S	F	S	S	F	F
Loans	F	F	-	S	S	S	S	S
Project Financing	F	F	-	S	S	S	S	S
Shares	-	-	F	F	F	S	S	S
Private Sector Funding	F	F	-	S	S	S	S	S
Special Project Funds	S	S	F	S	F	S	F	S
Limited Recourse Structures								
BOT	-	-	S	S	S	S	F	S
BOOT	S	S	F	S	S	S	S	S
Non-Cash Contribution	S	S	S	F	-	-	-	-
Retention Schemes	S	S	P	S	S	S	S	S
Alternative Funding	S	F	-	F	F	S	F	F
International Funding	-	-	S	-	F	F	F	-

Key of Symbols used in Table 3

S—The model is very suitable to fund this type of SDI or component of the SDI. The most efficient application of this model would be to this category of an SDI.

F—The application of the model to this type of SDI or component of the SDI is favourable. Although the model can adequately fund this category of an SDI (in some cases) it would not be the most efficient application of the model.

8. ANALYSIS

The results of the research indicate that SDSM can be an advantageous tool to SDI funding. It facilitates the SDI community in modelling the performance of the funding models over time and under specified conditions. In modelling the implementation environment SDSM allows the users to track and analyse the behaviour of the funding models and or the implementation environment at any instant in time. The research shows that applying SDSM to SDI funding will allow the community to better predict the following: the expected cost of implementation, the amount of funds individual models can generate over a given period of time, the reaction of the models to expected or unexpected changes in the implementation environment, and the best possible integration of the models in funding a particular SDI. In addition, the SDSM also enables program managers to visualise the predictions through its graphic display of the results. This is an important feature since a visual display of the dynamics of the funding activities can both enhance and complement the analysis of the numbers.

The application of SDSM to SDI funding is not, however, without limitations. Firstly, the SDS models are only as effective as the modeller's knowledge of the funding models and the implementation environment. That is, the greater the modeller's knowledge of the implementation environment and the factors affecting the application of the funding models the more reliable the results—the effects of changes in the implementation milieu on the funding models over time—of the SDS models. Secondly, the coding of this knowledge into the SDS models, and the verification and validation of the SDS models are partly based on circular logic. This is due, in part, to the nature of SDSM which is based on the concept of feedback loops; where information from the system is fed back into the model to create new models.

9. CONCLUSION

The paper explored the possibility of applying the SDSM technique to the funding issues of an SDI. The paper discussed the concept of SDSM and the benefits it offers in the study of the funding milieu of an SDI. The authors presented examples of SDS models developed in their research. These SDS models and the results of their runs were used to demonstrate the capabilities of the SDSM techniques in analysing and evaluating the performance of the funding models.

Although the results of the research to date indicates that the SDSM technique does offer some benefits to the SDI community further research is still required. The authors are of the opinion that further research would greatly improve the quality and credibility of the SDS models thus improving their ability to evaluate not only the performance of the funding models but also to better analyse the implementation milieu.

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